APPENDIX A
SUPERCRITICAL UNITS

1.0 INTRODUCTION

This appendix includes data gathered on supercritical units. The objective of this exercise was to present the relationship between the development of the technology over time with respect to the capital cost. The relationship of technology maturity to price per kW could then be applied to the development of the clean coal technology presented in the main portion of this document.

This presentation of data on supercritical plants is based on information available from various sources. This information is a presentation of costs, plant components, and environmental controls; no attempt was made to develop operating costs for each of the plants. The Utility Data Institute, which provided a majority of the costing information, provides capital cost data in the year dollars the plant was constructed. There is no scope breakdown of the capital cost.

2.0 DATA

Cost data for pulverized coal supercritical units and subcritical units were gathered from various sources. Table 1 is a listing of sources used to compile the data presented herein. These data are presented as reported in Figure 1. Figure 2 presents these costs levelized to 1996 constant dollars. The cost data presented in Figure 2 include funds during construction.

Various attempts were made to normalize the data presented in Figure 1 to determine a predictable trend, rather than the scatter shown in Figure 1. Figure 3 has the data normalized to a 500 MW plant size. These data include all U.S. pulverized coal plants (supercritical and subcritical), including funds during construction. The data have been levelized to 1996 constant dollars and normalized to a 1.0 labor factor, thereby eliminating regional workforce differences.

Further attempts were made to segregate the data. Figure 4 presents U.S. subcritical plants, adjusted to 500 MW, including funds during construction, with the costs levelized to 1996 constant dollars and normalized to a 1.0 labor factor. Figure 5 goes one step further and normalizes these plants to contain a single unit; therefore, Figure 5 presents U.S. subcritical

plants, adjusted to 500 MW with a single unit, including funds during construction, with the costs levelized to 1996 dollars, and normalized to a 1.0 labor factor.

Figure 6 presents data for U.S. supercritical units, adjusted to 500 MW, including funds during construction, with the costs levelized to 1996 constant dollars, and normalized to a 1.0 labor factor. Figure 7 goes one step further and normalizes these plants to contain a single unit; therefore, Figure 7 presents U.S. supercritical plants, adjusted to 500 MW with a single unit, including funds during construction, with the costs levelized to 1996 dollars, and normalized to a 1.0 labor factor.

Additional attempts were made to identify trends in similar type facilities. Figure 8 shows U.S. supercritical units firing bituminous medium sulfur or high sulfur coal with flue gas desulfurization units, adjusted to 500 MW with a single unit, including funds during construction, with the costs levelized to 1996 dollars, and normalized to a 1.0 labor factor. Figure 9 presents U.S. supercritical units firing bituminous low sulfur coal without a flue gas desulfurization system, adjusted to 500 MW with a single unit, normalized to a 1.0 labor factor, including funds during construction, with constant 1996 dollars.

Figure 10 presents the trends of subcritical and supercritical plants in the U.S. over the last 30 years. Figure 11 adds the trend of plants built in foreign countries. Figure 12 presents the reported costs of foreign pulverized coal plants, adjusted to 500 MW size and to 1996 constant dollars. Very limited information is available for foreign power plants prior to 1991. Figure 13 displays international pulverized coal costs segregated by country.

Figure 14 exhibits the labor cost factor by region of the United States. This figure illustrates the differences in the labor rate depending on the region. Information from Figure 14 was used to adjust all costs presented to the national average or a 1.0 labor cost factor.

Figure 15 illustrates the components of investment for a 400 MW pulverized coal supercritical plant.

3.0 ANALYSIS

As previously stated, attempts were made to normalize all the data. To normalize for the region in which the plant was built, the labor factors presented in Figure 14 were utilized to equate the plant to a national average labor factor. All cost data gathered from published sources are in the year dollars that the plant came on line. These costs were escalated to 1996 constant dollars by use of the Handy-Whitman formula.

Figures 1 through 7 generally show increasing costs of building power plants. The results seen in these graphs are the influence of site-specific components, environmental regulations, and the scope of work included in the cost numbers reported. Figure 8 shows a decrease in the cost of building supercritical units with FGD, while Figure 7 shows an increase in overall plant cost. This is postulated to be due to the decrease in the cost of the FGD system rather than a decrease in the plant cost.

Plant costs are dependent on technology, time frame, and site. Increasing environmental regulations cause plants to add more equipment (e.g., FGD systems), lose potential capacity, and lose efficiency. Advanced technologies may have a higher capital cost, and be incorporated into the facility. These technologies will reduce operating costs, thereby reducing production costs; however, the data presented herein are solely a presentation of capital costs. The time frame in which the plant was built could have a significant impact on the capital cost, and the use of union or nonunion labor will also have a significant impact. The location in which the plant is built could also have a significant impact other than the labor rate, which we have normalized, because construction techniques differ depending upon the region. In the South, structures may be left open, and neither heat tracing nor train thawing is required. However, in the North, structures are enclosed, and the facility requires more insulation, as well as heat tracing or freeze protection.

The most significant factor influencing the data presented herein is the scope of the costs reported. We have no way of equalizing all costs reported to include similar items. Permitting and licensing may or may not be included. Civil amenities (e.g., fence, road, railway, geotechnical liners, etc.) may or may not be included. Byproduct (e.g., bottom ash, fly ash, FGD waste)

disposal areas may or may not be included. A second unit on an existing site will have lower capital costs reported, due to site facilities already being in place.

Limited historical information was available for the international units. Most of the data presented are cost estimated data for current or future construction.

4.0 CONCLUSION

The data presented are capital cost data, with little supporting information. All attempts at normalizing or levelizing the data to get a true trend analysis failed. The data are historical, which provides relationships between data points; however, to get a true concept of the power plant development of the last 20 years, more information is required. The relationship between technology maturity and capital cost was not shown in the data gathered.

Table 1

Source No.	Title	Title of Journal/Periodical	Date	Year
1	Assesment of Supercritical Power plant Performance	EPRI CS-4968	December	1986
2	Electric Power Plant Construction Costs	UDI-2053-96	April	1996
3	Power	Vol 140	April	1996
4	Power	Vol. 137	April	1993
5	Sven Kjaer. Elsam 400 MW coal-fired USC power plant Investigation	3rd Conference on Improved coal POwer plants	April	1991
6	Highest Supercriticality for Skaerbaek and Nordiylland	Modern Power Systems	March	1995
7	Al Taweelah B	Modern Power Systems Supplement	July	1995
8	A 500 MW Coal Fired CHP Plant for Rostok	Modern Power Systems Supplement	February	1992
9	World Digest	Modern Power Systems	September	1996
10	Advanced coal fired technology for Meri-Pori	Modern Power Systems - Supplement	March	1993
11	French Coal Expirience Leads to Technology Export	Modern Power Systems - Supplement	December	1991
12	World Digest	Modern Power Systems	March	1995
13	World Digest	Modern Power Systems	August	1996
14	World Digest	Modern Power Systems	January	1996
15	World Digest	Modern Power Systems	September	1995
16	Power Supply Outlook for the 1990s by P.J. Adams	1989 Power-Gen		
17	Development Plan for Advanced Fossil Fuel Power Plants	EPRI CS-4029	May	1985
18	Comparison of Options for Generating Electricity from Coal in California	Prepared for PG&E by Stearns Catalytic	December	1986
19	Advanced Power Systems and Coal Quality	IEA Coal Research, IEACR/87	May	1996

Figure 1

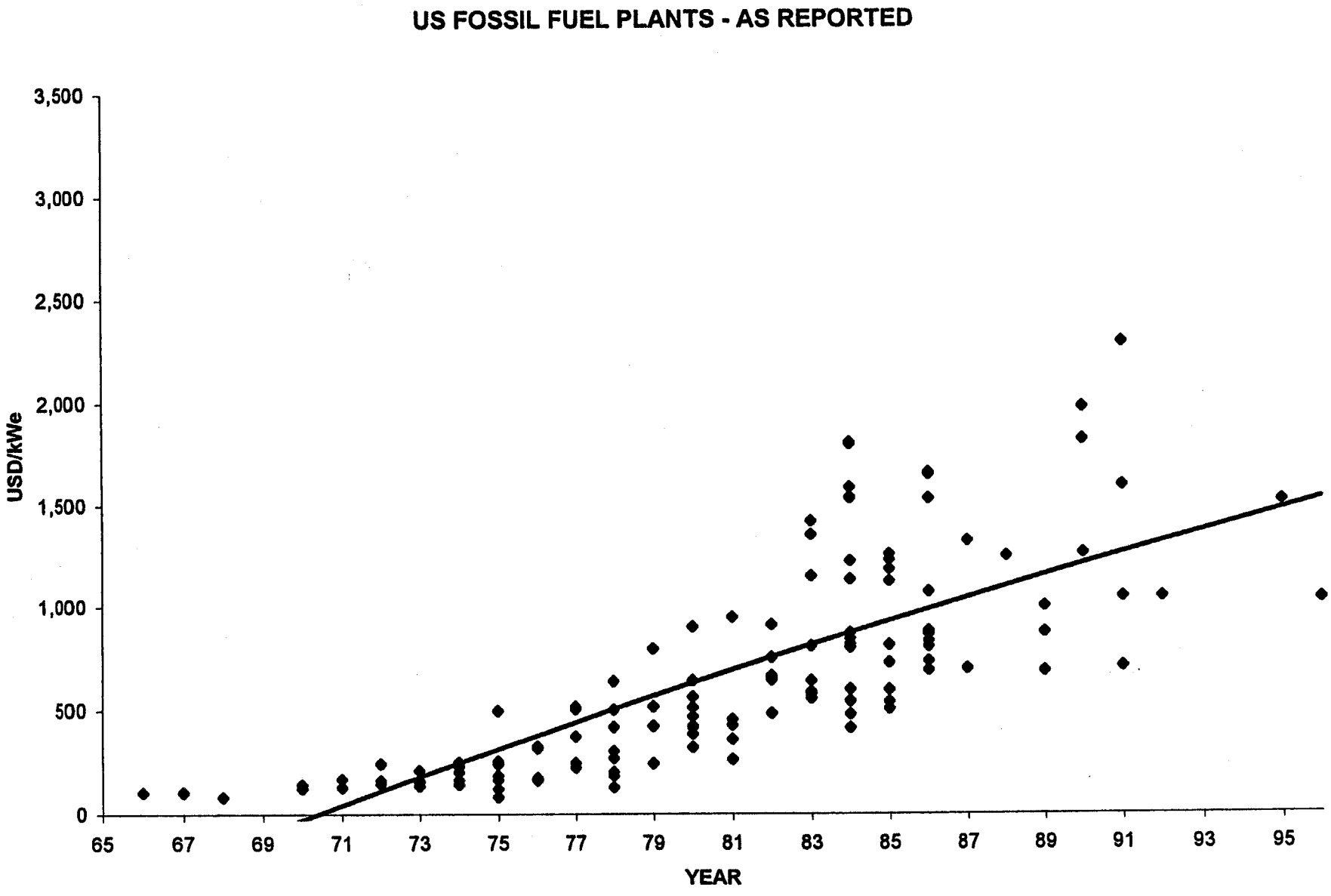

US FOSSIL FUEL PLANTS - AS REPORTED
USD/kWe
3,500
3,000
2,500
2,000
1,500
1,000
500
0
65
67
69
71
73
75
77
79
81
83
85
87
89
91
93
95
YEAR

Figure 2

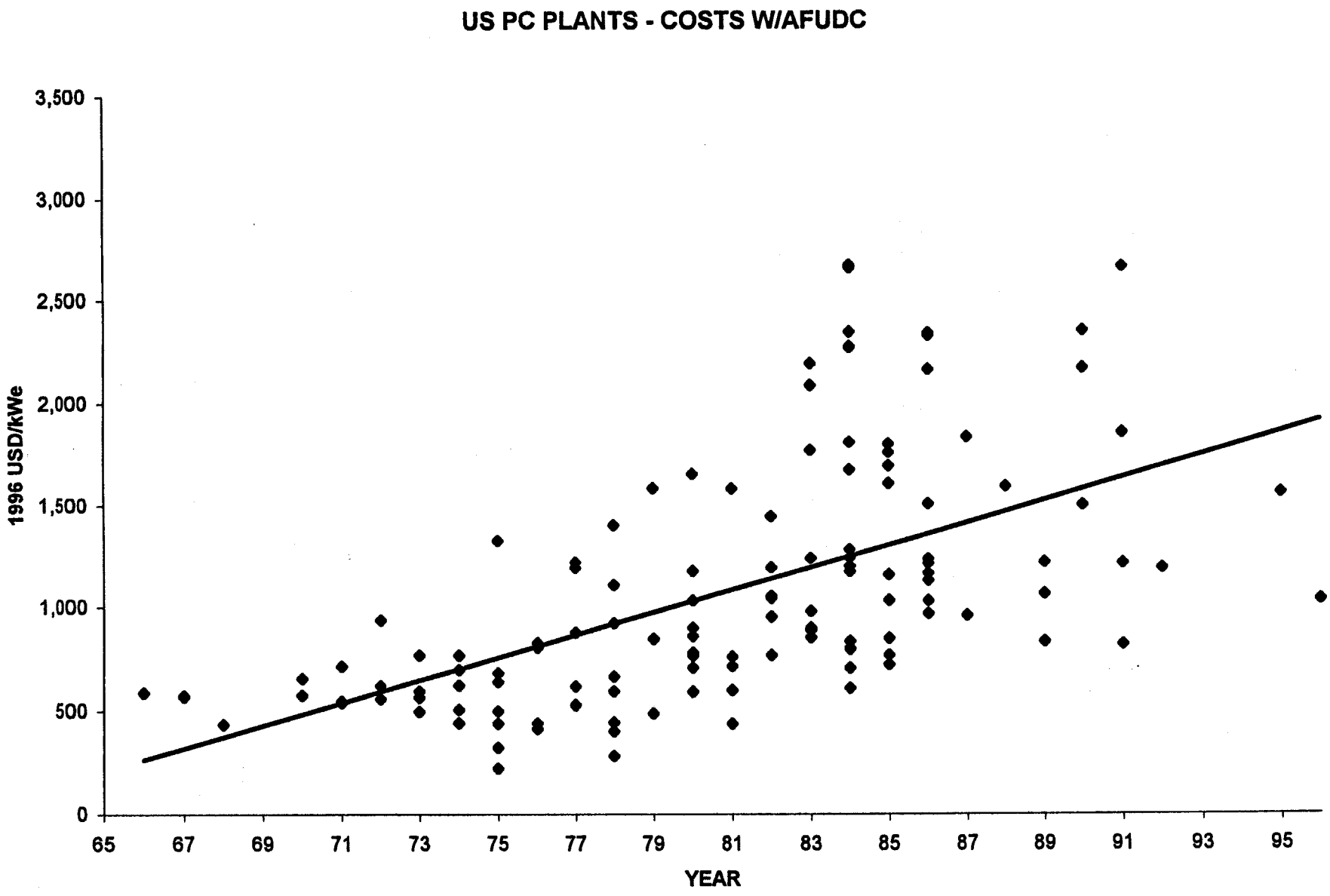

US PC PLANTS - COSTS W/AFUDC
1996 USD/kWe
3,500
3,000
2,500
2,000
1,500
1,000
500
0
65
67
69
71
73
75
77
79
81
83
85
87
89
91
93
95
YEAR

Figure 3

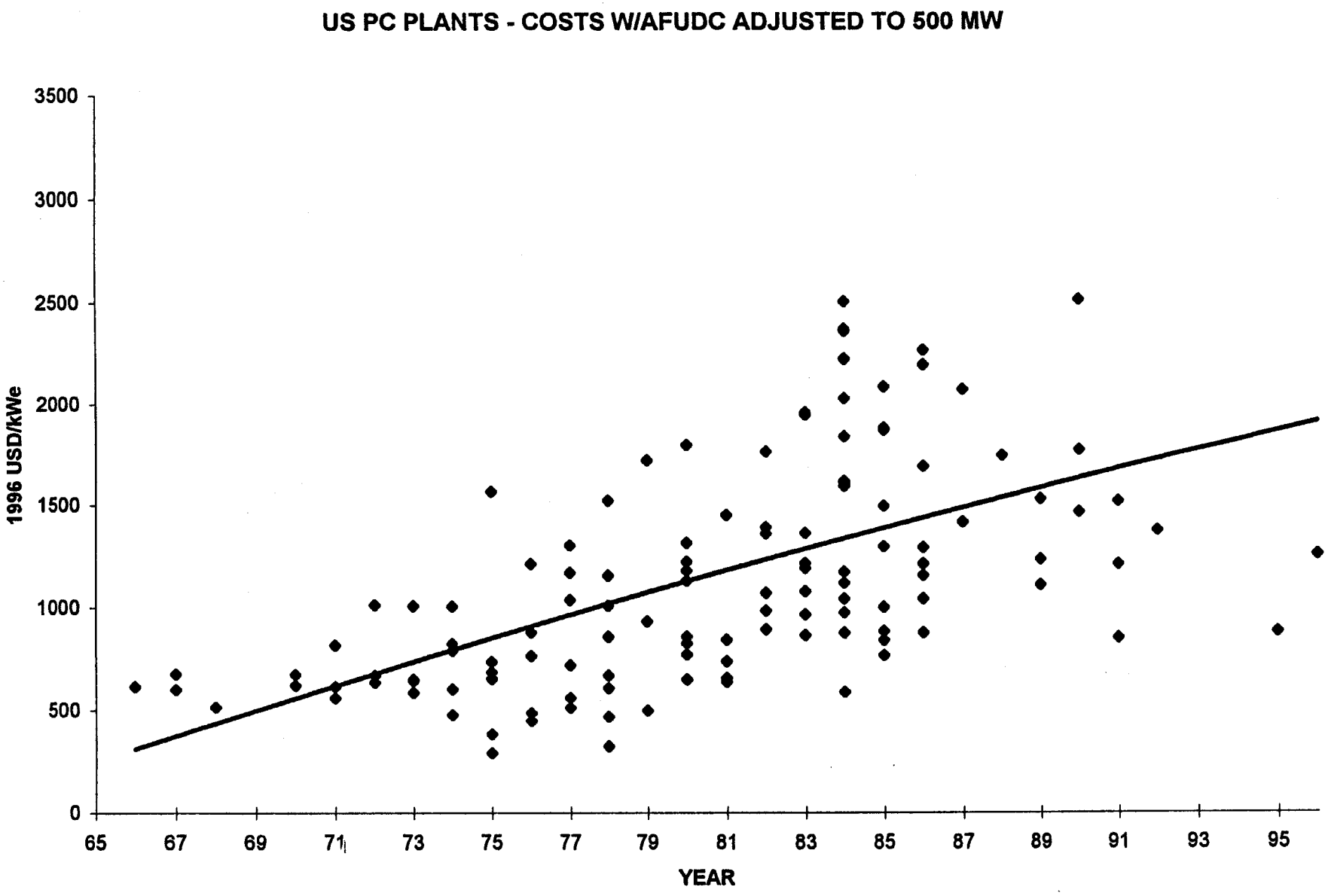

US PC PLANTS - COSTS W/AFUDC ADJUSTED TO 500 MW
1996 USD/kWe
3500
3000
2500
2000
1500
1000
500
0
65
67
69
71
73
75
77
79
81
83
85
87
89
91
93
95
YEAR

Figure 4

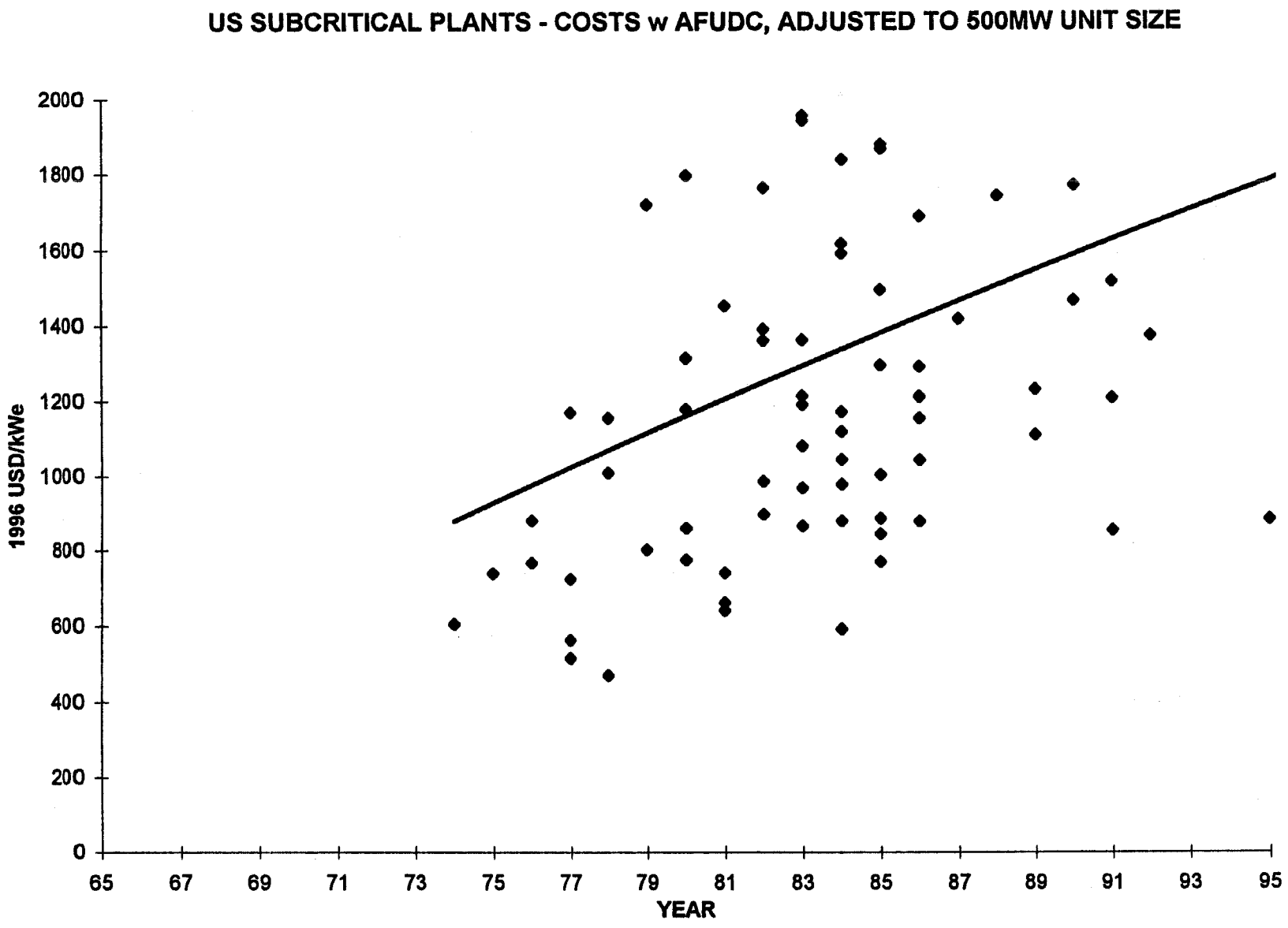

US SUBCRITICAL PLANTS - COSTS w AFUDC, ADJUSTED TO 500MW UNIT SIZE
1996 USD/kWe
2000
1800
1600
1400
1200
1000
800
600
400
200
0
65
67
69
71
73
75
77
79
81
83
85
87
89
91
93
95
YEAR

Figure 5

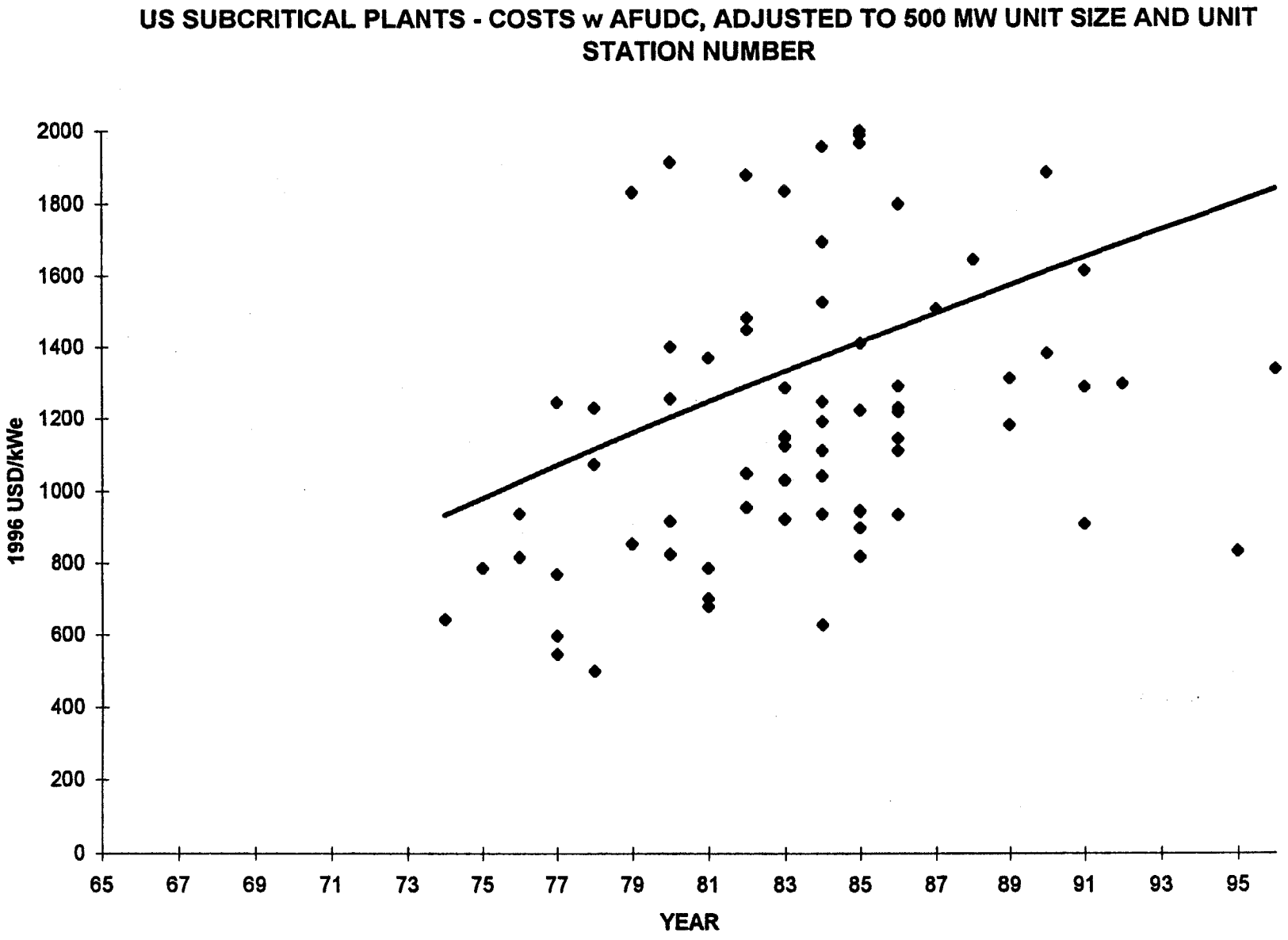

US SUBCRITICAL PLANTS - COSTS w AFUDC, ADJUSTED TO 500 MW UNIT SIZE AND UNIT STATION NUMBER
1996 USD/kWe
2000
1800
1600
1400
1200
1000
800
600
400
200
0
65
67
69
71
73
75
77
79
81
83
85
87
89
91
93
95
YEAR

Figure 6

US SUPERCRITICAL PLANTS - COSTS w AFDUC, ADJUSTED TO 500 MW UNIT SIZE

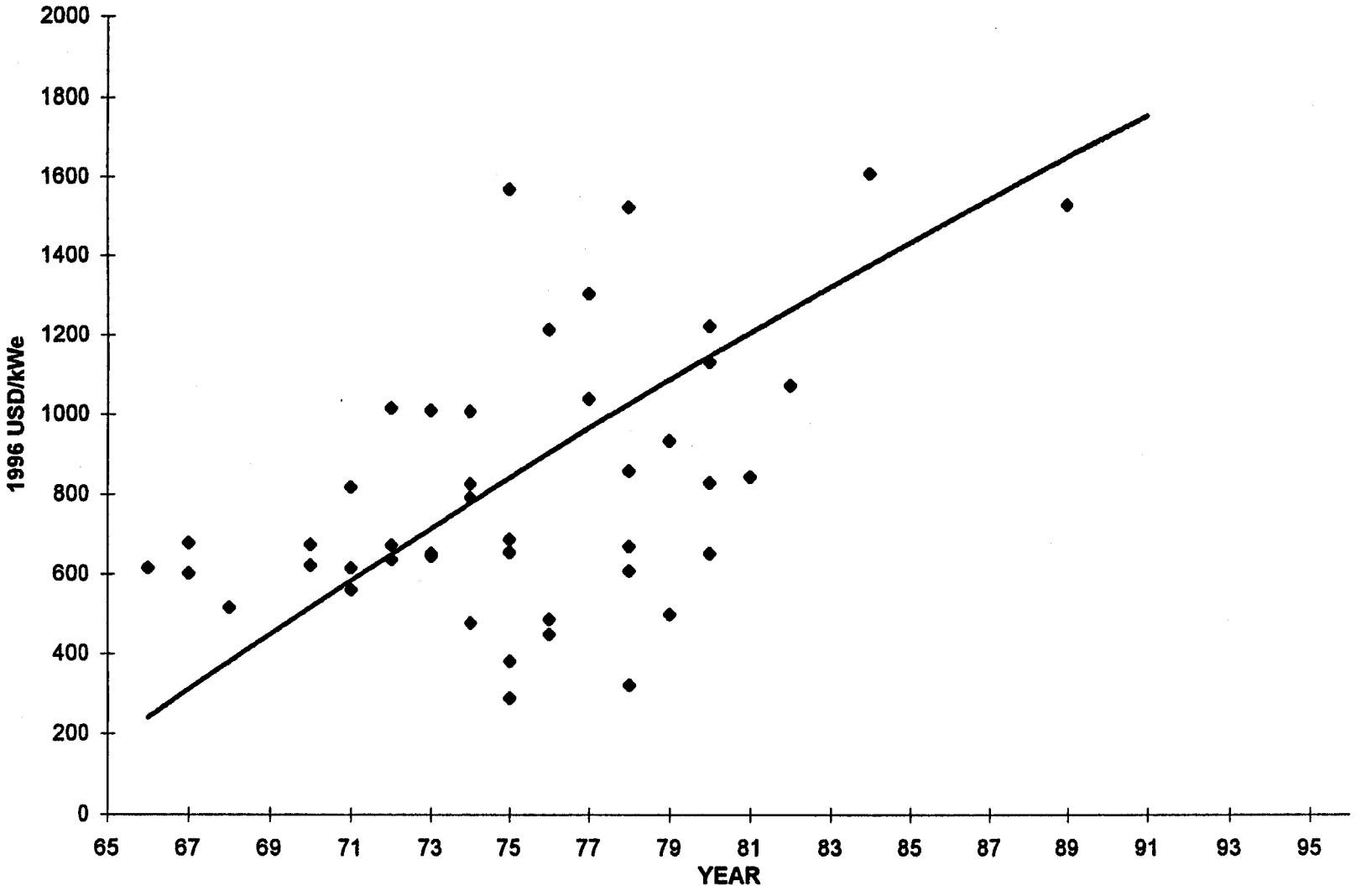


Figure 7

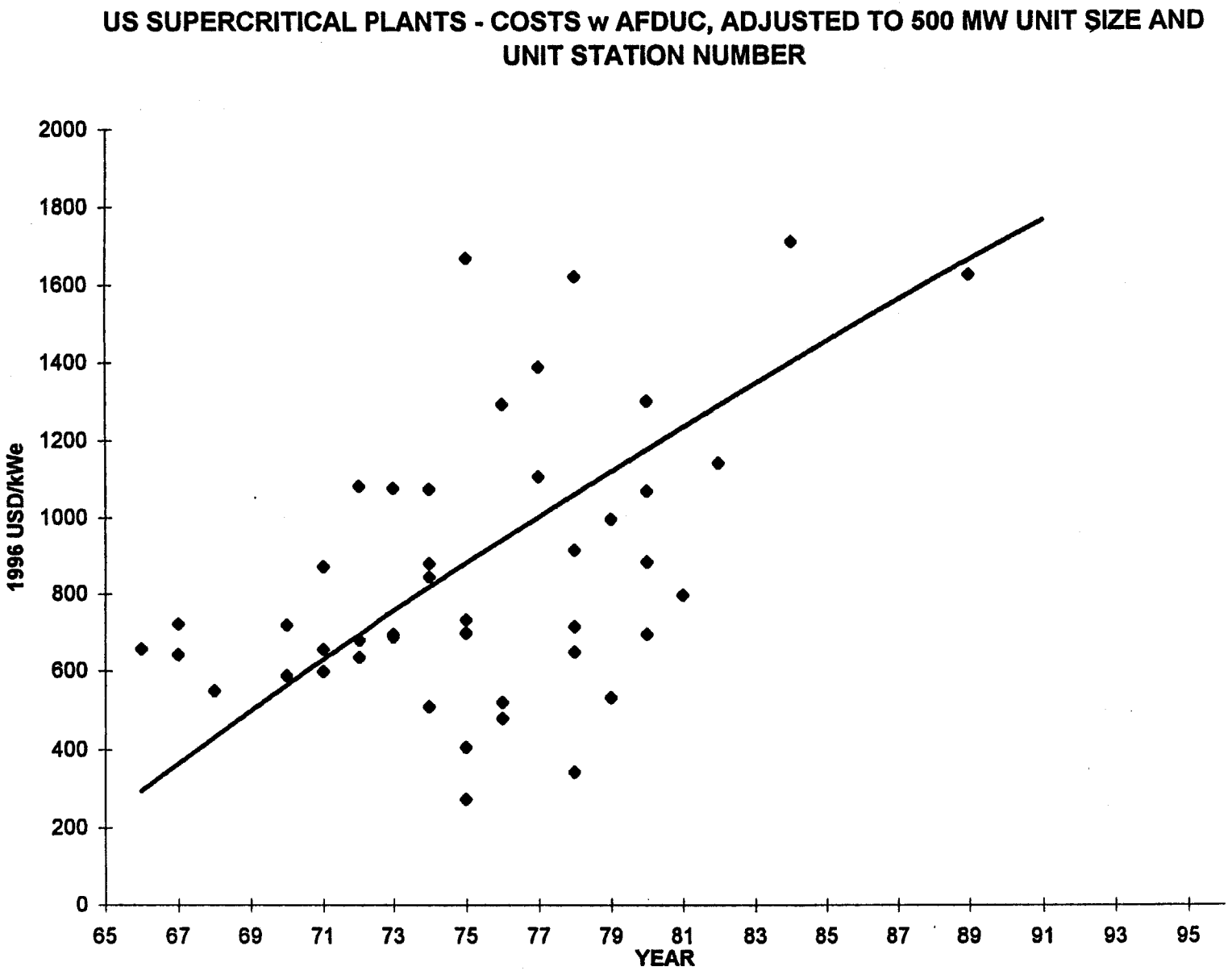

US SUPERCRITICAL PLANTS - COSTS w AFDUC, ADJUSTED TO 500 MW UNIT SIZE AND UNIT STATION NUMBER
1996 USD/kWe
2000
1800
1600
1400
1200
1000
800
600
400
200
0
65
67
69
71
73
75
77
79
81
83
85
87
89
91
93
95
YEAR

Figure 8

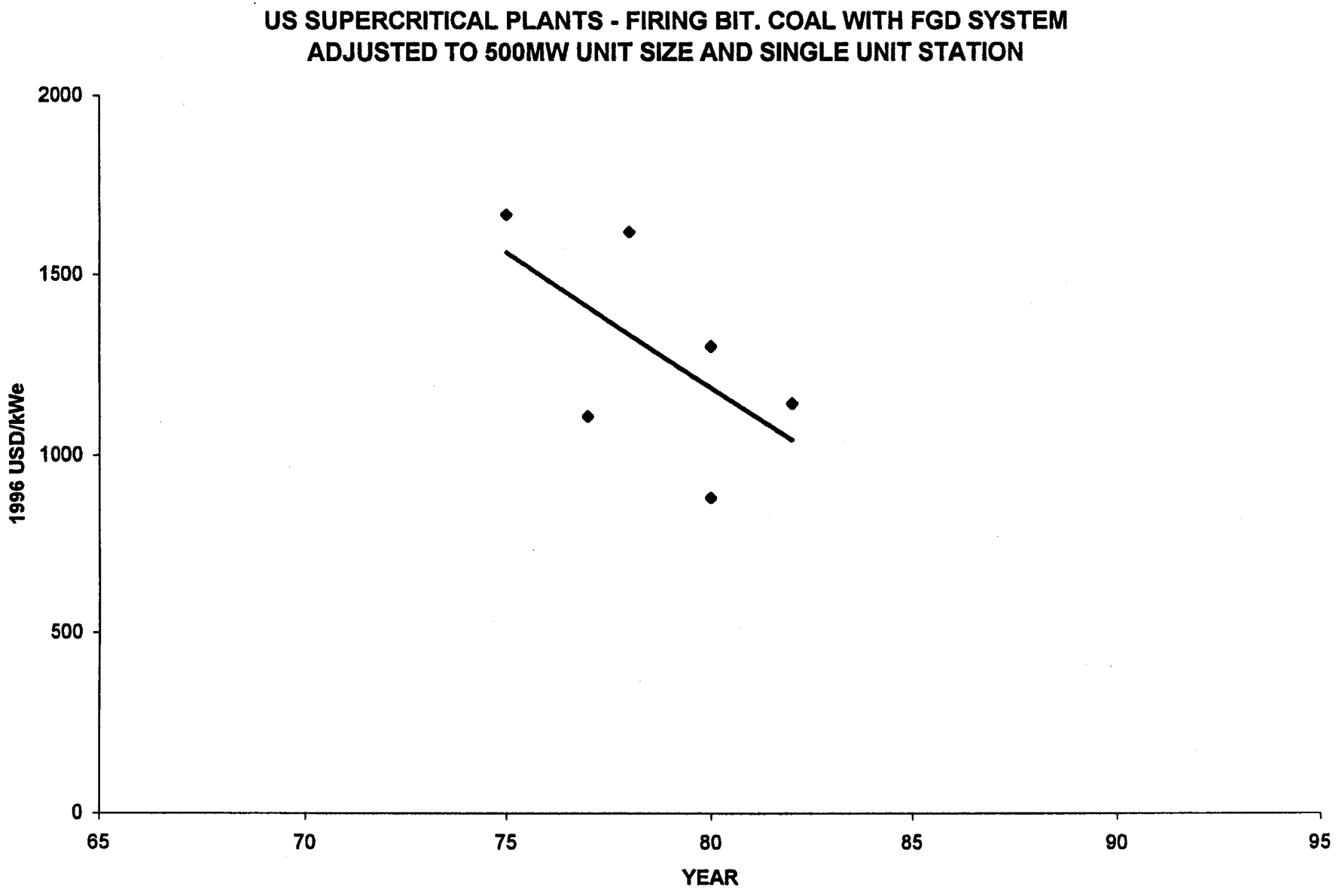

US SUPERCRITICAL PLANTS - FIRING BIT. COAL WITH FGD SYSTEM
ADJUSTED TO 500MW UNIT SIZE AND SINGLE UNIT STATION
2000
1500
1000
500
0
1996 USD/kWe
65
70
75
80
85
90
95
YEAR

Figure 9

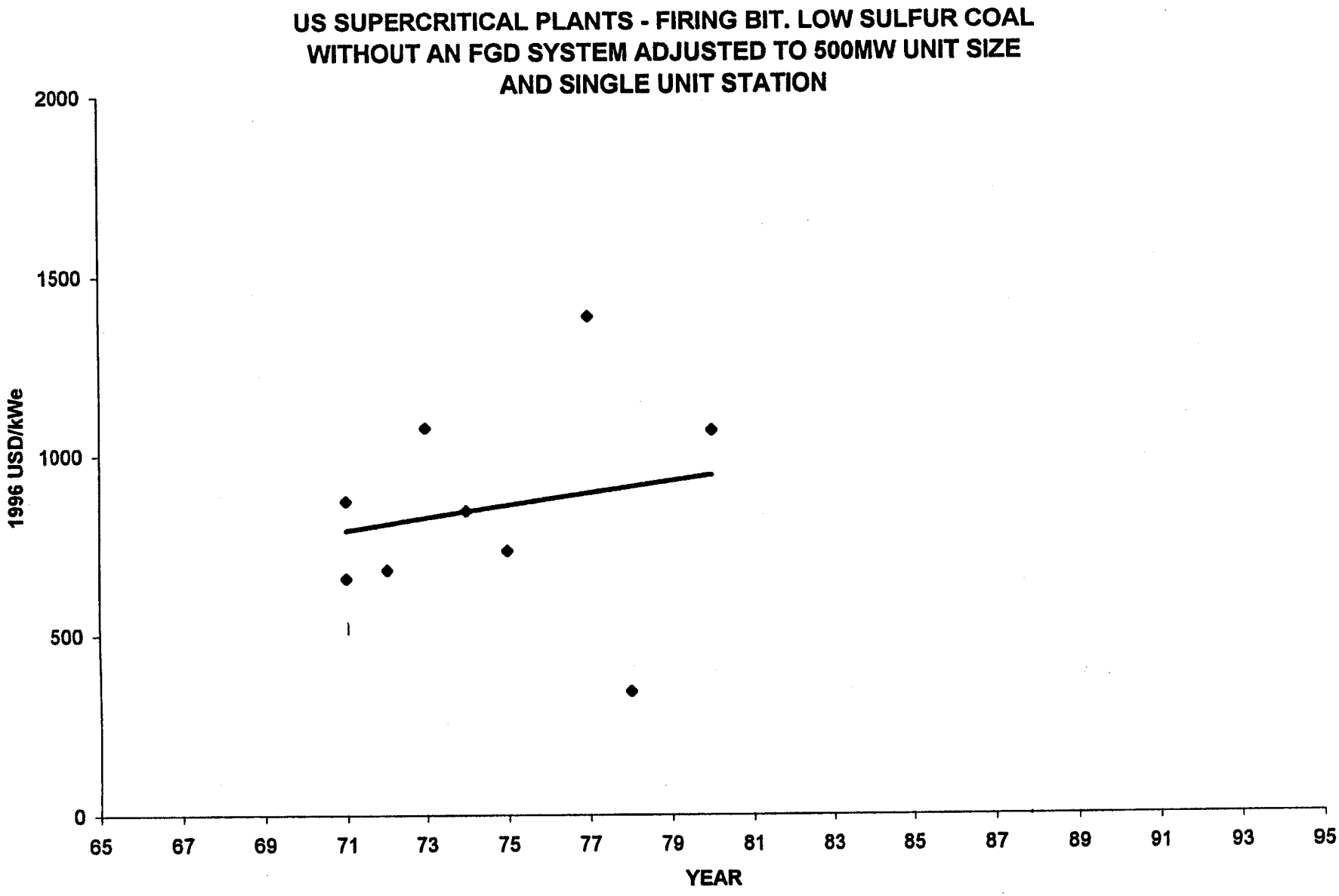

US SUPERCRITICAL PLANTS - FIRING BIT. LOW SULFUR COAL
WITHOUT AN FGD SYSTEM ADJUSTED TO 500MW UNIT SIZE
AND SINGLE UNIT STATION
1996 USD/kWe
2000
1500
1000
500
0
65
67
69
71
73
75
77
79
81
83
85
87
89
91
93
95
YEAR

Figure 10

US PC PLANTS COST HISTORY

500MW Avg.Unit Cost

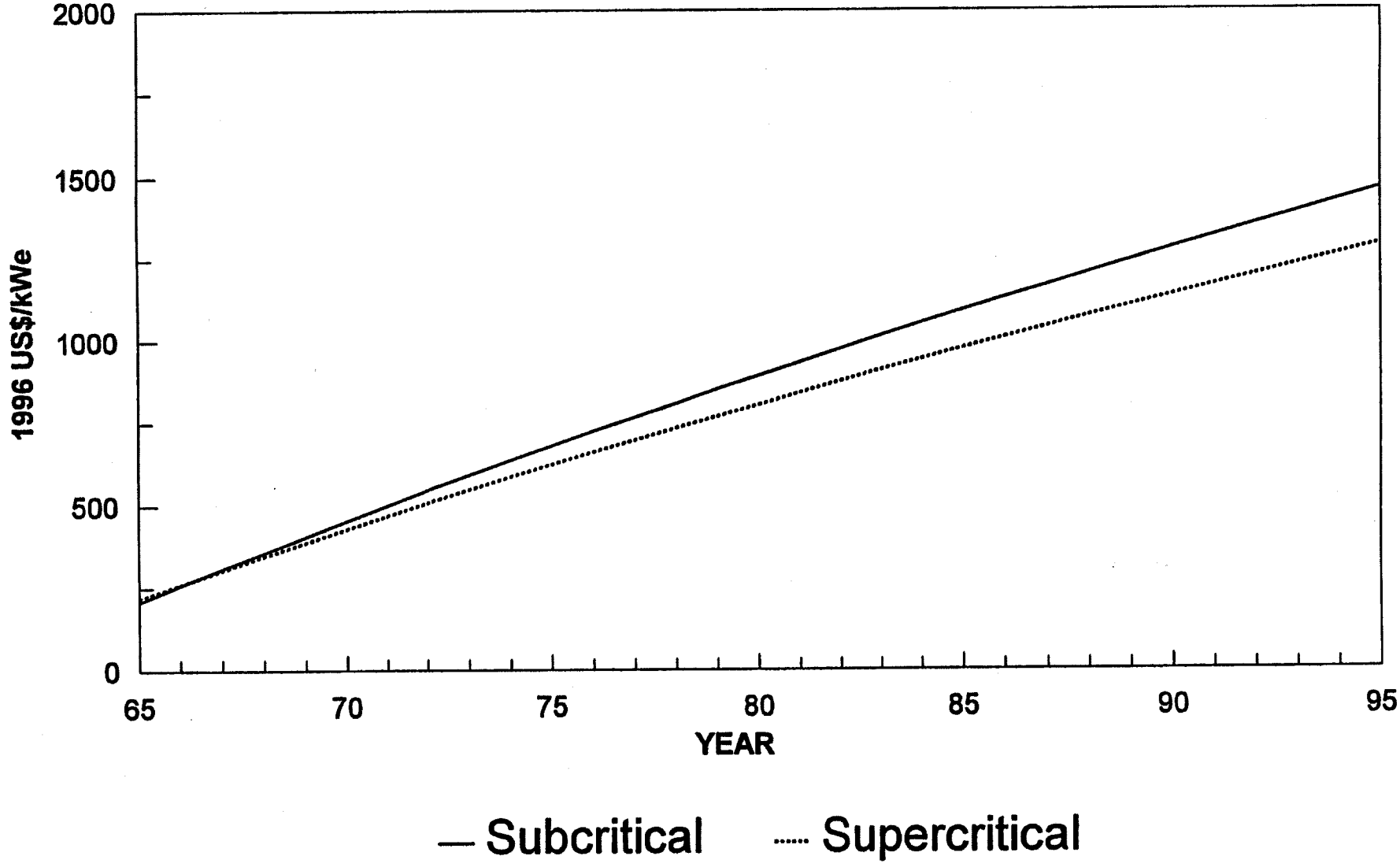


Figure 11

US PC PLANTS COST HISTORY

500MW Avg.Unit Cost

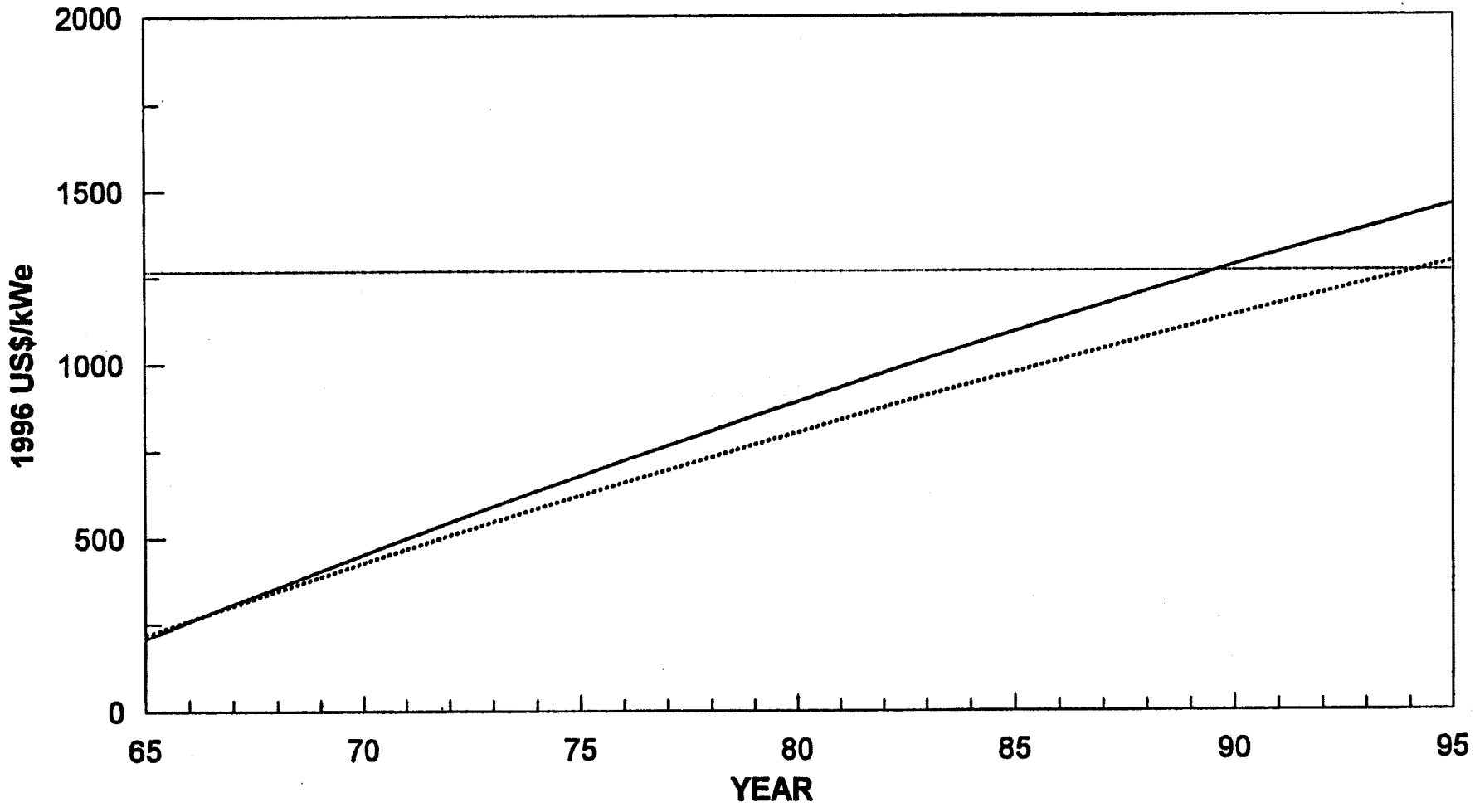


Figure 12

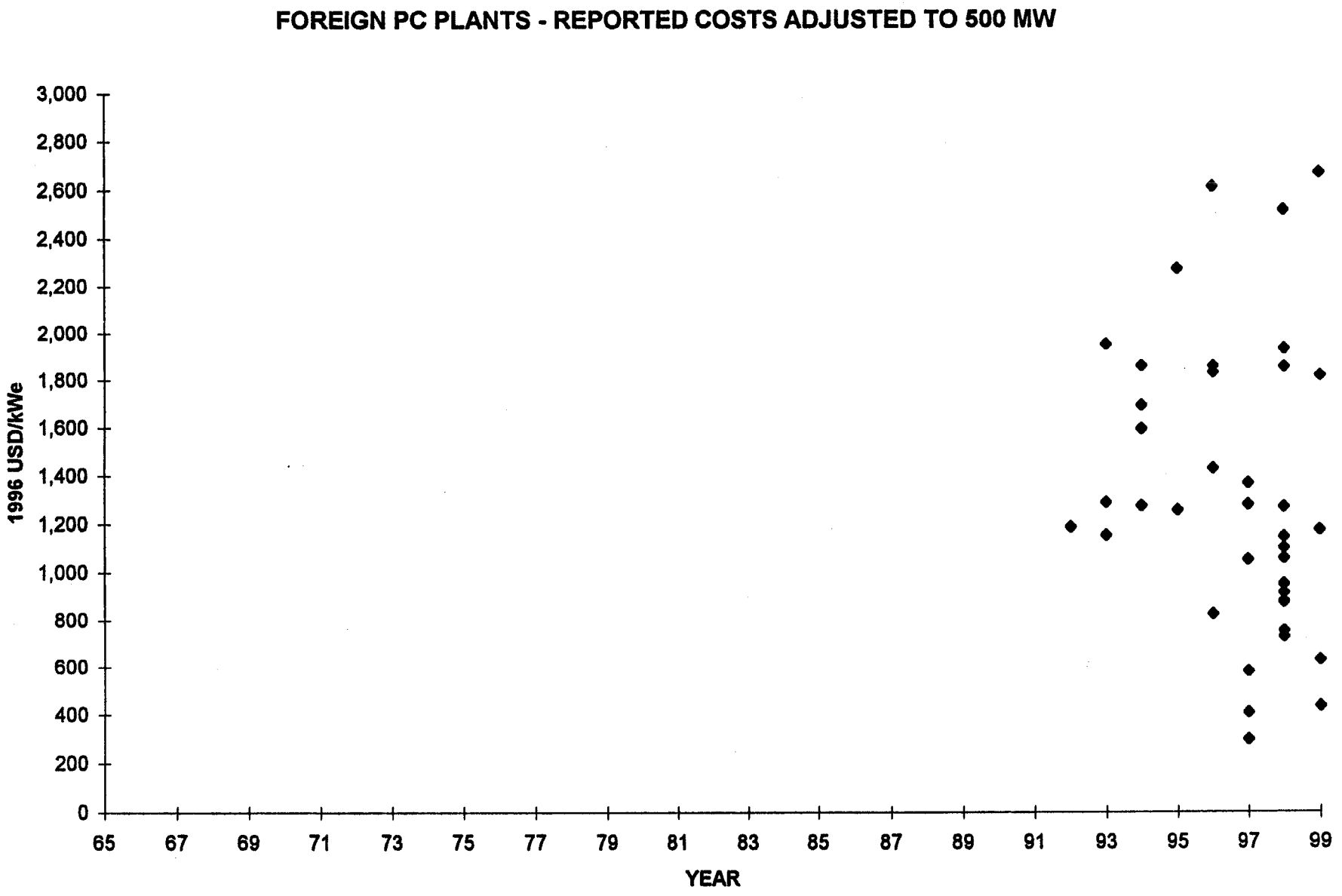
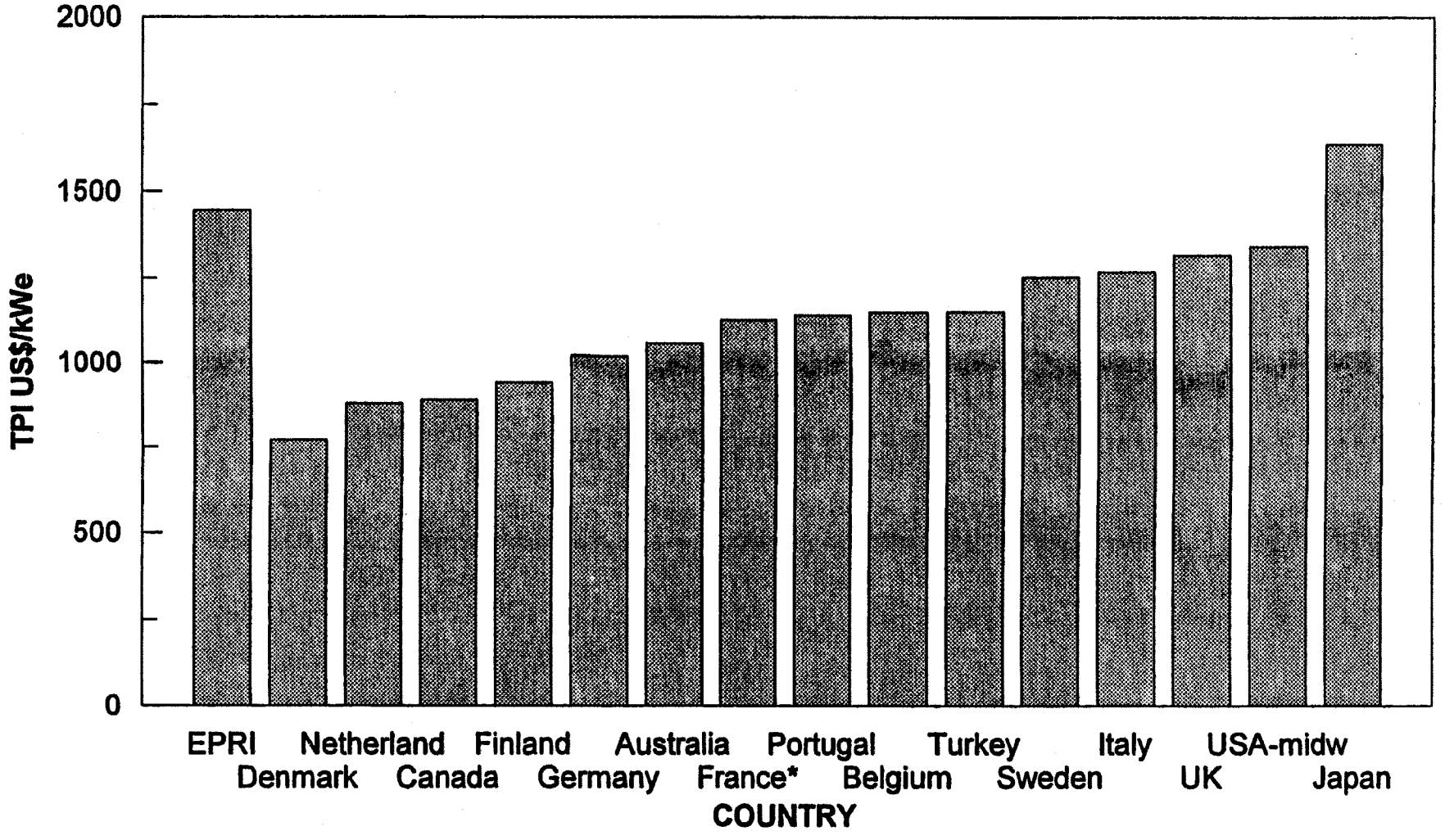

FOREIGN PC PLANTS - REPORTED COSTS ADJUSTED TO 500 MW
1996 USD/kWe
3,000
2,800
2,600
2,400
2,200
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
65
67
69
71
73
75
77
79
81
83
85
87
89
91
93
95
97
99
YEAR

Figure 13

INTERNATIONAL PC PLANT COSTS

Total Plant Investment - Discounted Cash Flow Basis



Data not normalized, except as 1996 $
Costs are estimates, except *=constructed

Figure 14

Regional Construction Labor Factors

Northeast	0.727802
Ohio River Valley	0.957854
Southeast	1.686341
Midwest	0.825764
Central	0.935454
South Central	1.347709
West Coast	0.809061
Northwest	0.94518
Hawaii	0.773395